

# Application of Terrestrial Environments in Orion Assessments

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# Outline

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- Introduction to Natural Environments
- Description of the Multi-Purpose Crew Vehicle Program's (MPCV's) Orion Vehicle
- Examples of Terrestrial Environments Support
  - Design
  - Test
  - Mission
- Summary

# Introduction to Natural Environments

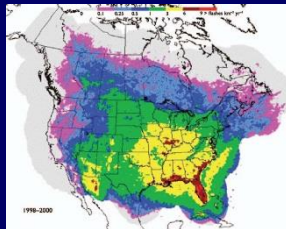
# Natural Environment Concerns

- The “Natural Environment” is a phenomena that occur regardless of human constructed objects.
- Vehicles are exposed to the natural environment throughout any mission.
- Mission phase and potential environmental considerations.
  - Pre-launch (ground winds, temperature, moisture, lightning, ionizing radiation)
  - Launch (ground and near-surface winds, visibility, lightning)
  - In-flight (winds aloft, atmospheric density, space environments, ionizing radiation, plasma, spacecraft charging)
  - Entry and descent (winds aloft, atmospheric density)
  - Landing and recovery (ground winds, visibility, sea conditions)
- Lifecycle consists of vehicle design and operation.
  - Robust design implies fewer operational constraints, but higher upfront cost.
  - Operational constraints are implemented when design is insufficient.
  - Design process must predict how the vehicle will be operated.
- Meteorological climatologies provide data to use in design phase, and one must address the same data during operations (e.g., wind constraint).

# MSFC NE Terrestrial and Planetary Environments Team

- Terrestrial and Planetary Environments (TPE) Team is part of the Marshall Space Flight Center Natural Environments (MSFC NE) Branch.
- Serve as a bridge between meteorological data collection sources and engineering analyses.
- Obtain and maintain meteorological archives.
  - Instrumentation at flight ranges and other sites of interest.
  - Global climatologies.
  - Implements quality control procedures and processes data for interrogation.
  - Develop in-house datasets and models.
- Define environment criteria for vehicle design.
- Provide tailored assessments to the engineering community for specific applications.

## DATA SOURCES

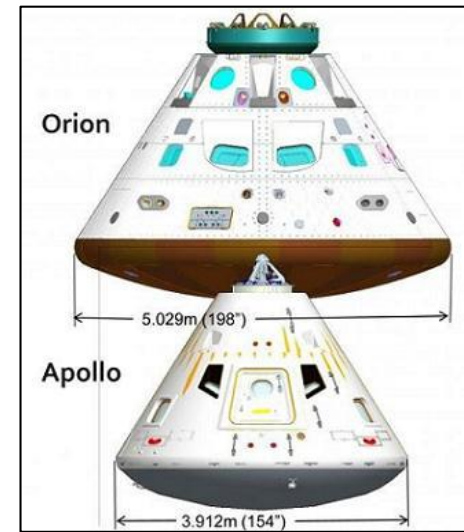
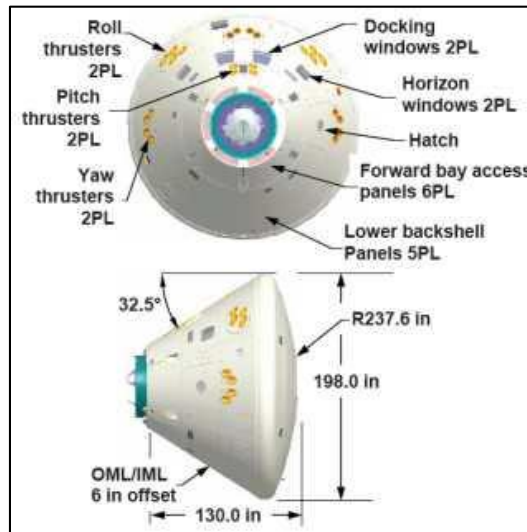
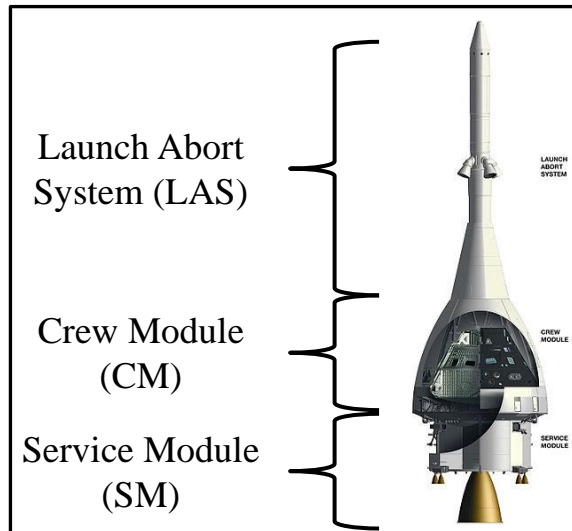


TPE

## APPLICATIONS



# Orion Description

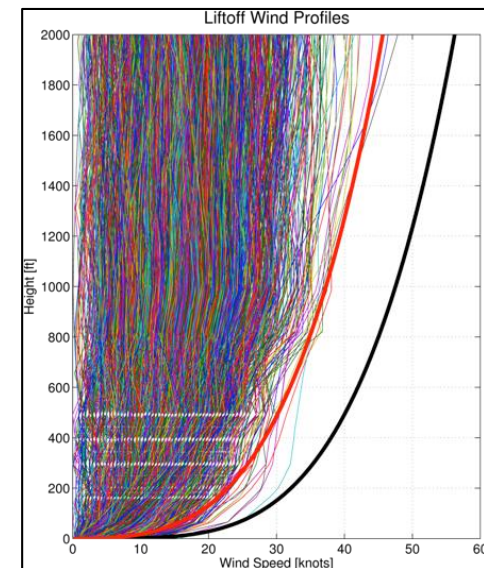
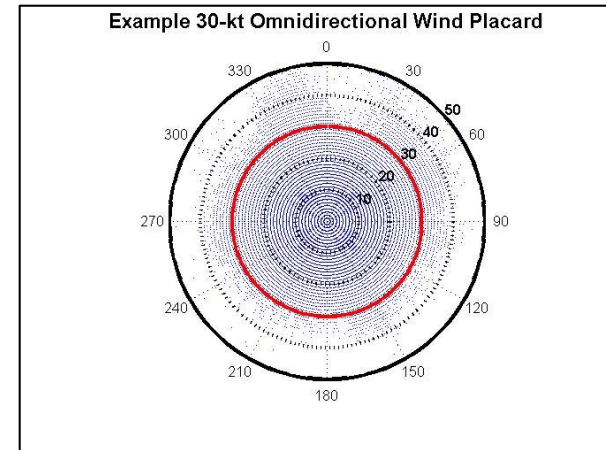


- Designed to carry astronauts beyond low-earth orbit.
- Originated during NASA's Constellation Program.
- Undergoing various tests.
  - Underway Recovery Test (URT)
  - Capsule Parachute Assembly System (CPAS) drop tests
  - Exploration Flight Test (EFT) – 1
  - Ascent Abort 2 (AA2)
  - Exploration Mission (EM) – 1 and EM – 2

# Examples of Support during Vehicle Design

# Launch Wind Constraint

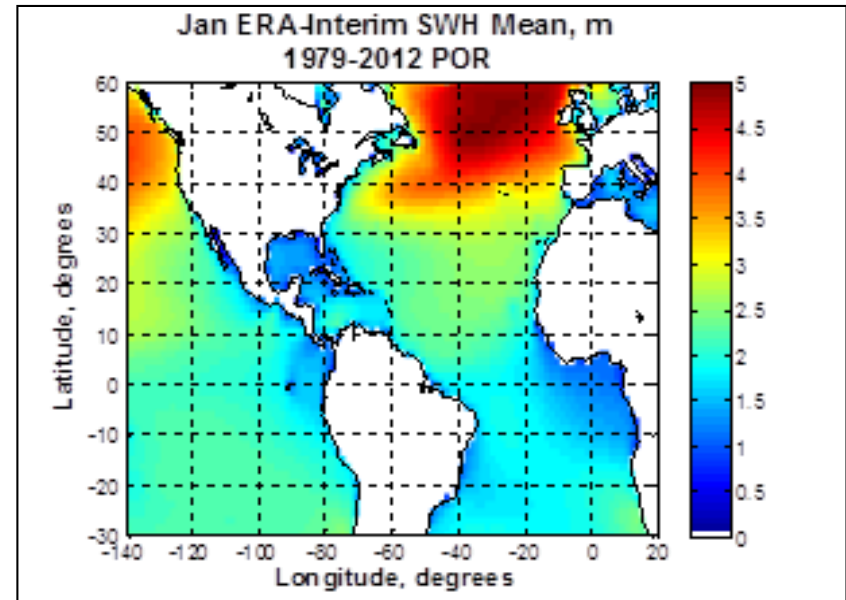
- Wind constraint is defined at 18.3 m, and depends on wind direction.
  - Adjust constraint based on vehicle sensitivities.
  - Process generates a constraint versus wind direction.
- Space Launch System (SLS) is designed to a peak wind profile based on a measurement at 18.3 m.
  - Log profile that envelopes winds given an 18.3 m wind.
  - Compare to measurements.
- Threshold determined during design evaluated on day-of-launch (several exist).
- SLS constraints apply to Orion for launch commit.





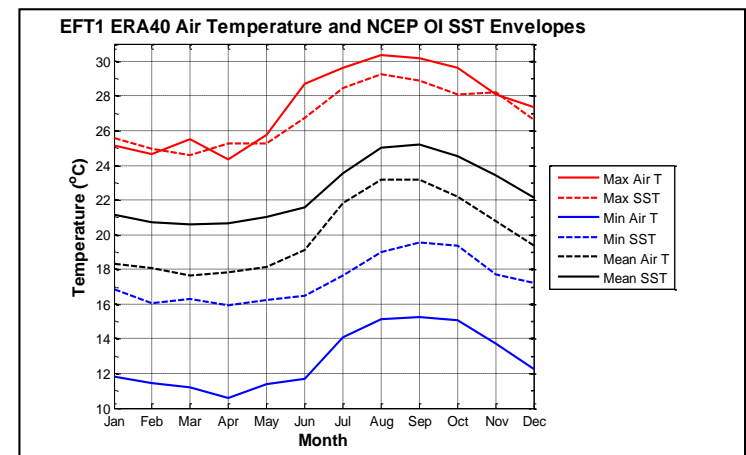
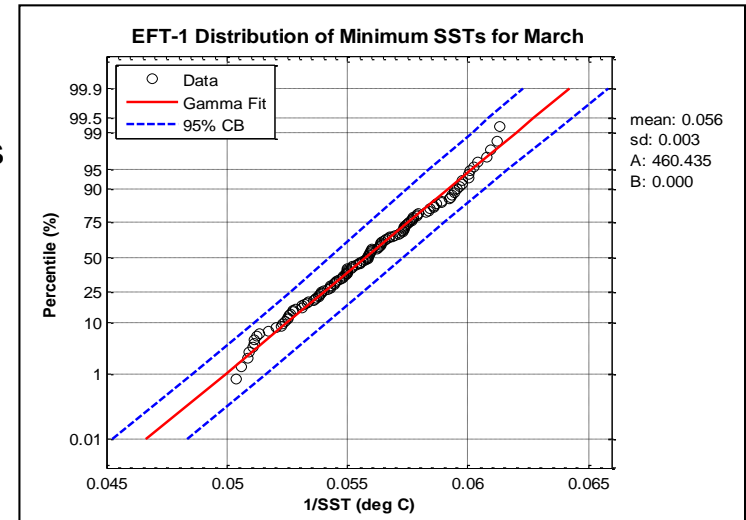
# Defining Sea Conditions

- Sea conditions influence the CM's landing and recovery limits.
- Usually do not apply to launch vehicles.
- Parameters of interest.
  - Significant wave height (SWH)
  - Wave period
  - Wind speed
- Use global climatologies to derive the probability of not exceeding specified constraints.
- Define constraints based on practical thresholds and probability of occurrence.



# Temperature for CMUS Helium Tanks

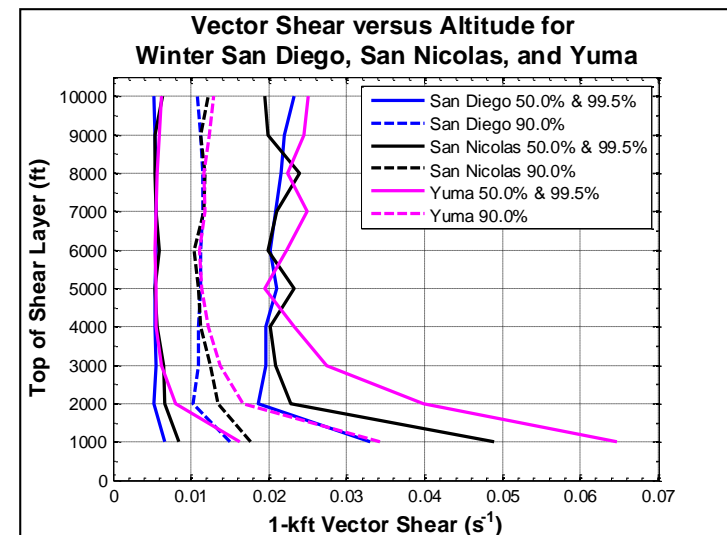
- Composite Overwrapped Pressure Vessels (COPVs) store helium to inflate CMUS bags.
  - Amount of helium needed to inflate the CMUS bags increases as temperature decreases.
  - Excessive helium exerts too much pressure on the COPV.
- Initial requirement was to fill bags at  $-2^{\circ}\text{C}$ .
- Performed analysis using multiple global climatologies to support increasing the ambient temperature threshold to  $10^{\circ}\text{C}$  for EFT-1.



# Examples of Orion Test Support

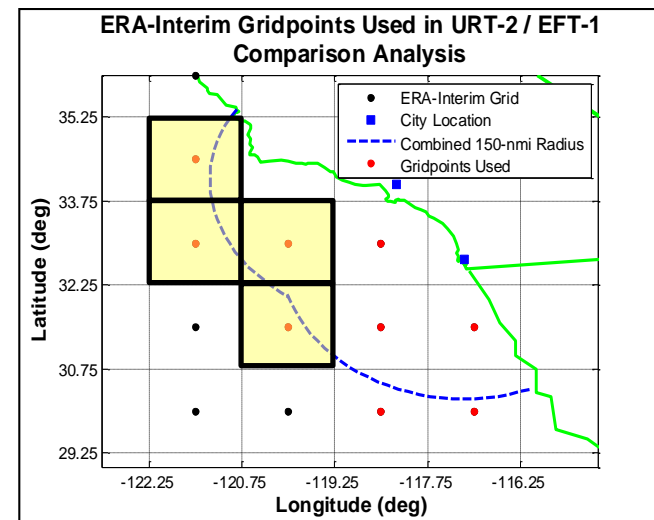
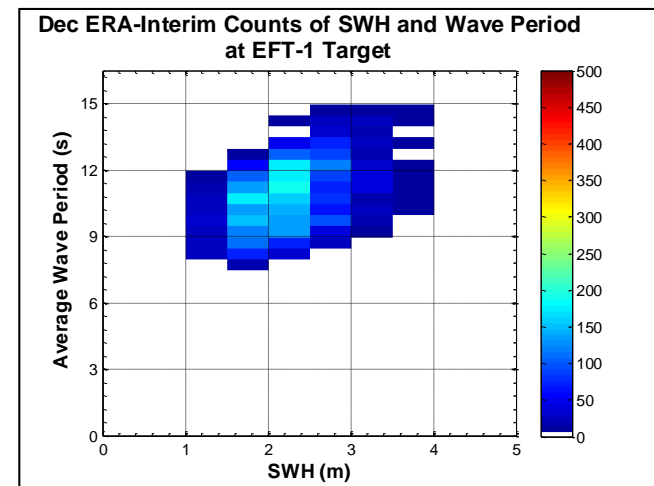
# Wind shear analysis for CM Descent

- CM can swing in various oscillatory modes late in descent.
- Compared wind shears from CPAS test site (Yuma, AZ) to near-shore locations.
  - Could shears generated near mountains exist at landing site?
  - Used balloon archives.
  - Found some differences below 5,000 ft.
  - Little differences where modes would start (as high as 10,000 ft).
- Verified balloon measurement accuracy.



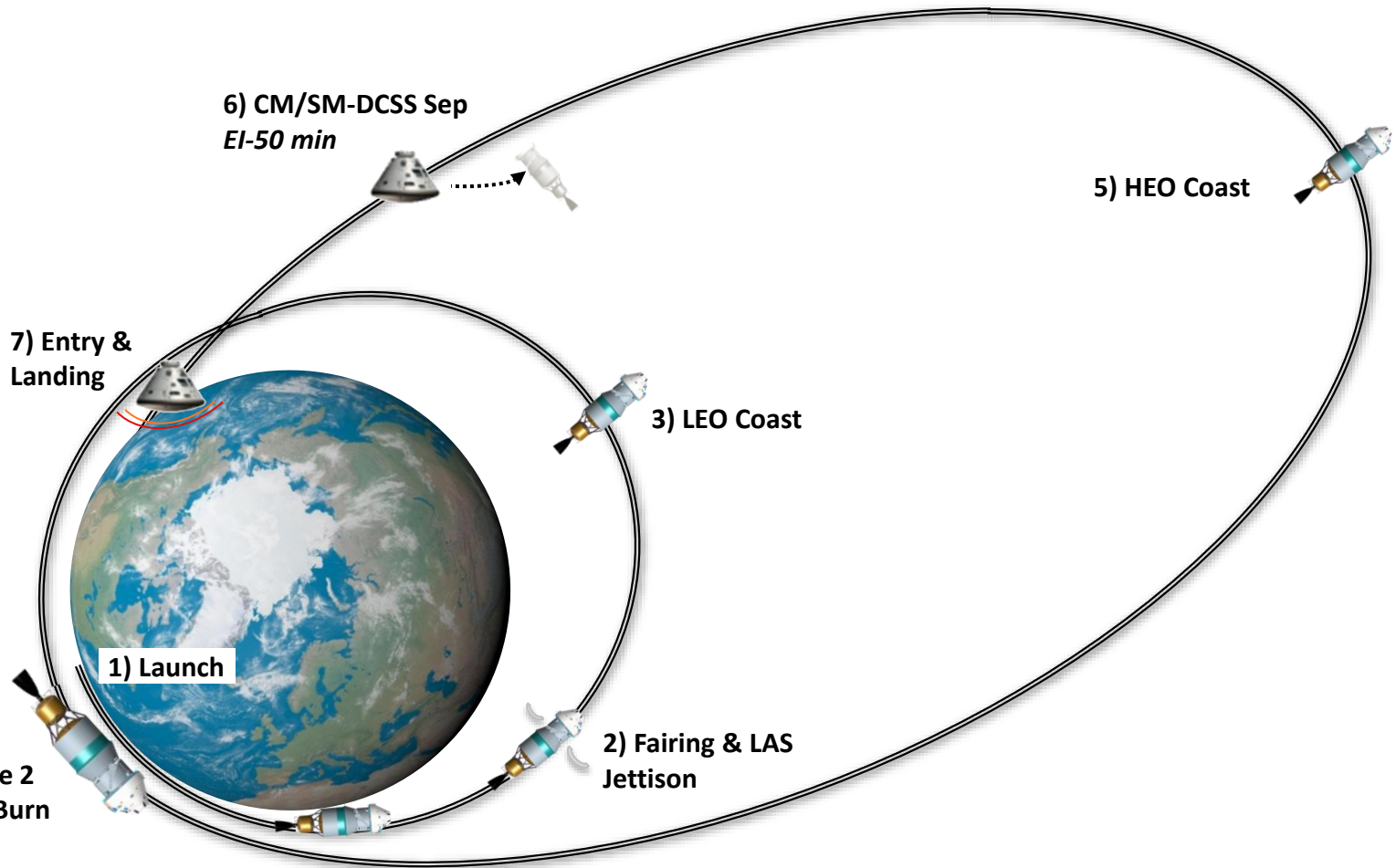
# Determining Optimal URT Locations

- Orion recovery personnel performed URTs leading up to EFT-1 off the CA coast.
  - EFT-1.
  - Off-nominal conditions.
- MSFC NE received request to quantify locations within the URT zone that climatologically best represent conditions at the EFT-1 site.
- Generated difference maps of concurrent SWH and average wave period counts between each gridpoint within the URT zone and the EFT-1 site.
  - Computed root mean square (RMS) difference from EFT-1 at each gridpoint.
  - Determined which gridpoints had lowest RMS differences.
- Concluded that testing in the west-northwest regions of the URT zone would likely best replicate EFT-1 conditions.
- Included caveat that this analysis is only based on climatology, and not any forecast.



# Examples of Orion Mission Support

# EFT-1 Mission Overview:



## Delta IV Heavy

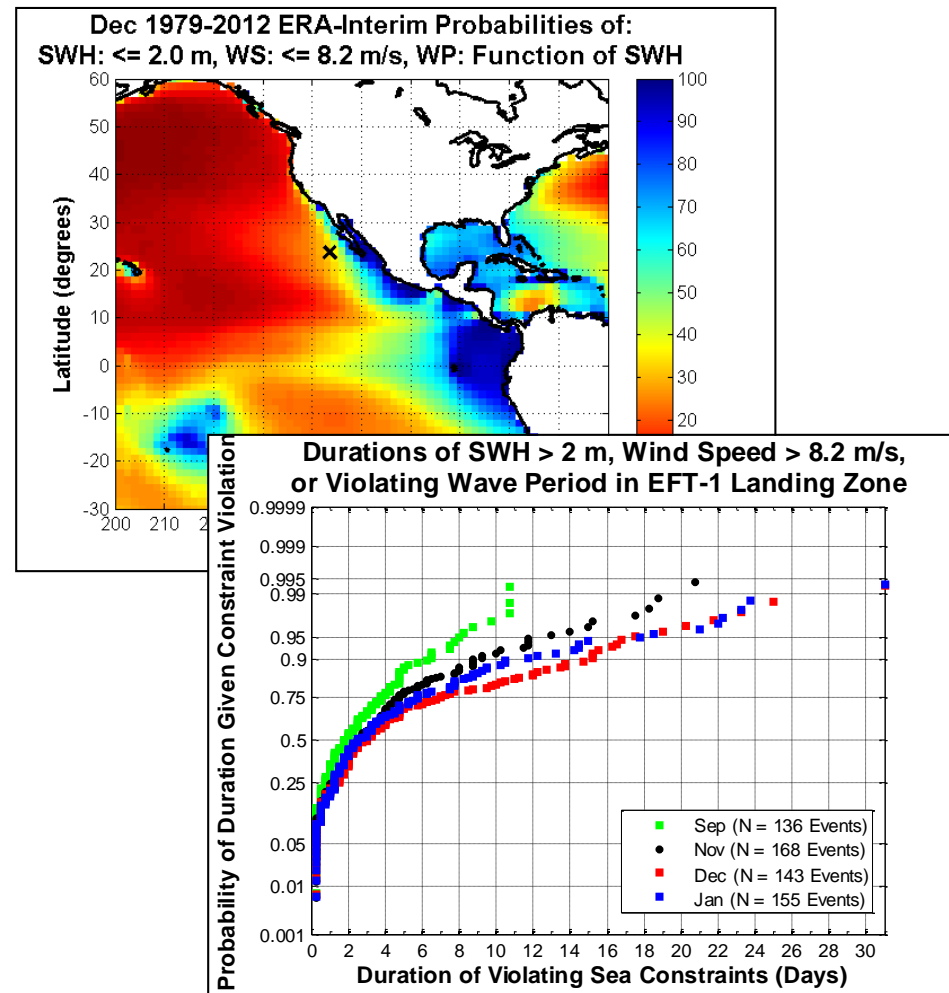
- 3 Common Booster Core
- DCSS Upper Stage

## Objectives

- Demonstrate core CM systems performance
- Demonstrate high energy entry ( $\sim 9$  km/s) and TPS performance
- Demonstrate integrated entry, descent, and landing operations

# EFT-1 Landing Availability

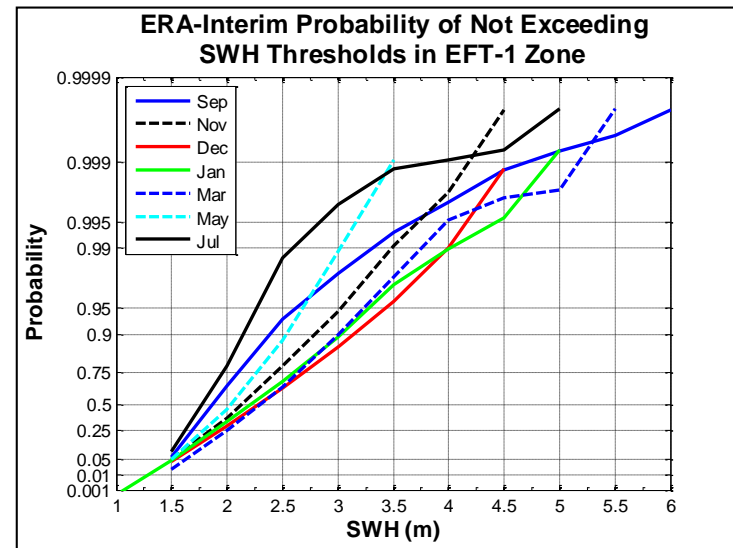
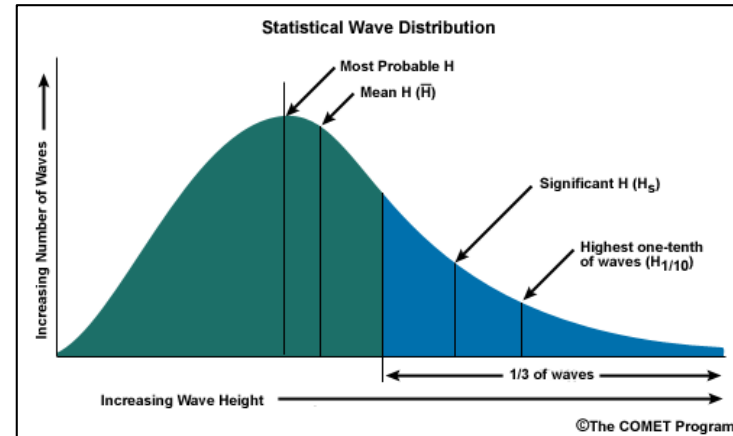
- For EFT-1, nominal landing conditions had to be met at launch.
- EFT-1 site exists within gradient of good and poor sea conditions.
- Questions arose relating to launching if landing conditions were marginally “no-go” at launch time.
  - “If we are no-go now, will we be no-go at landing?”
  - Requires climatological and forecast input.
- MSFC NE assessed the probability of violating sea condition constraints for specified durations.
  - Provides likelihood for staying no-go for a certain time.
  - Violating conditions persist longest during December.





# EFT-1 and Significant Wave Height

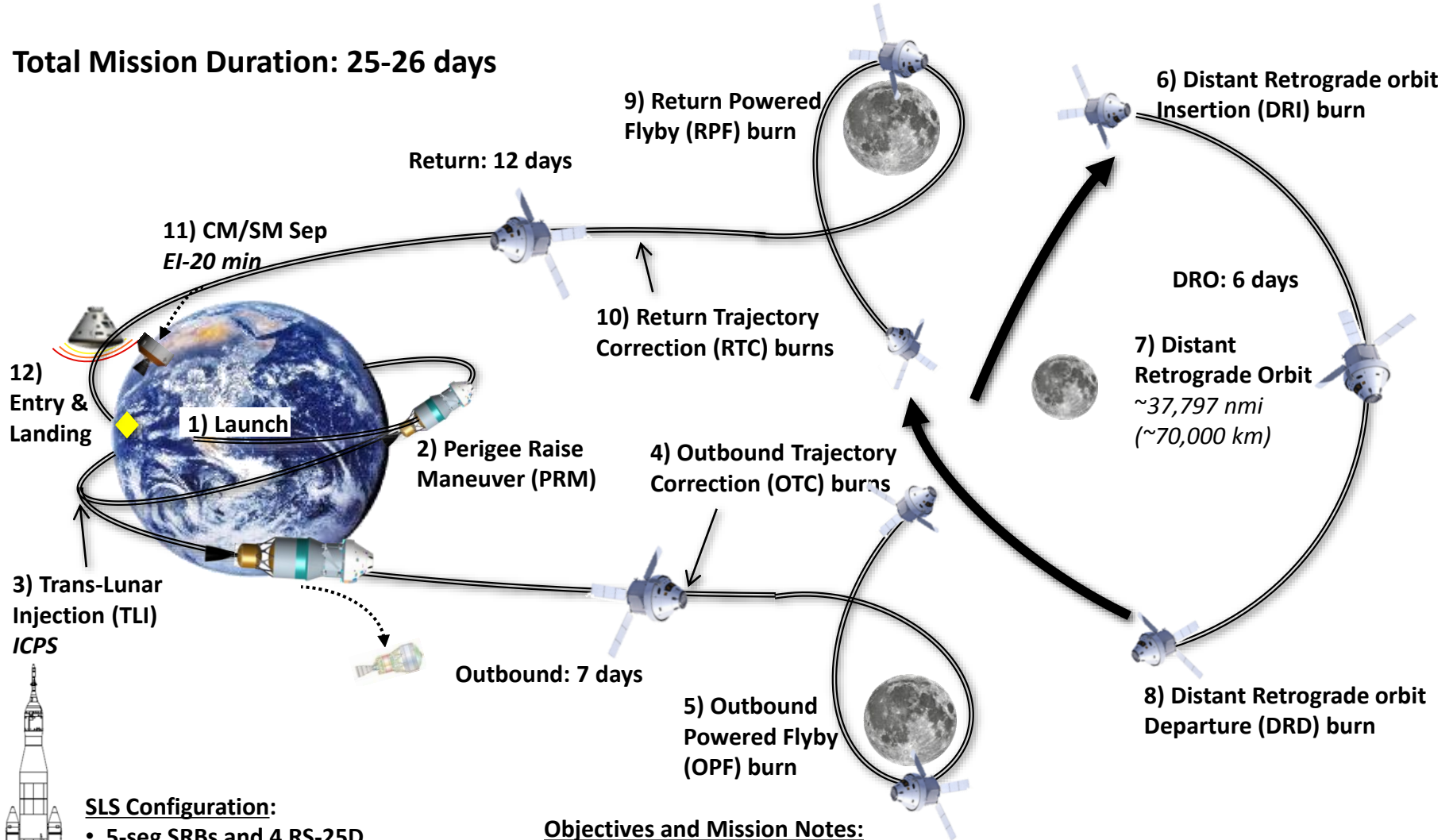
- SWH description
  - Represents average of the highest 1/3 of waves.
  - Computed directly from wave spectrum.
- SWH does not apply to Orion landing design, but is important for recovery operations.
- Recovery threshold is typically near 2 m SWH, but captain makes decision.
- EFT-1 originally scheduled for September, but moved to December, which led to accounting for higher seas.
- MSFC NE provided the probability of not exceeding different SWH for different months to MPCV.
  - Produces consequence of adjusting SWH limit.
  - Shows distribution of SWH for different months to support possibility of moving mission.



# EM-1: Uncrewed Distant Retrograde Orbit



Total Mission Duration: 25-26 days

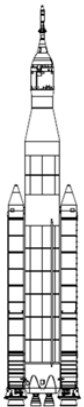


## SLS Configuration:

- 5-seg SRBs and 4 RS-25D
- Interim Cryogenic Propulsion Stage
- 28.5 – 35 deg inclination parking orbit

## Objectives and Mission Notes:

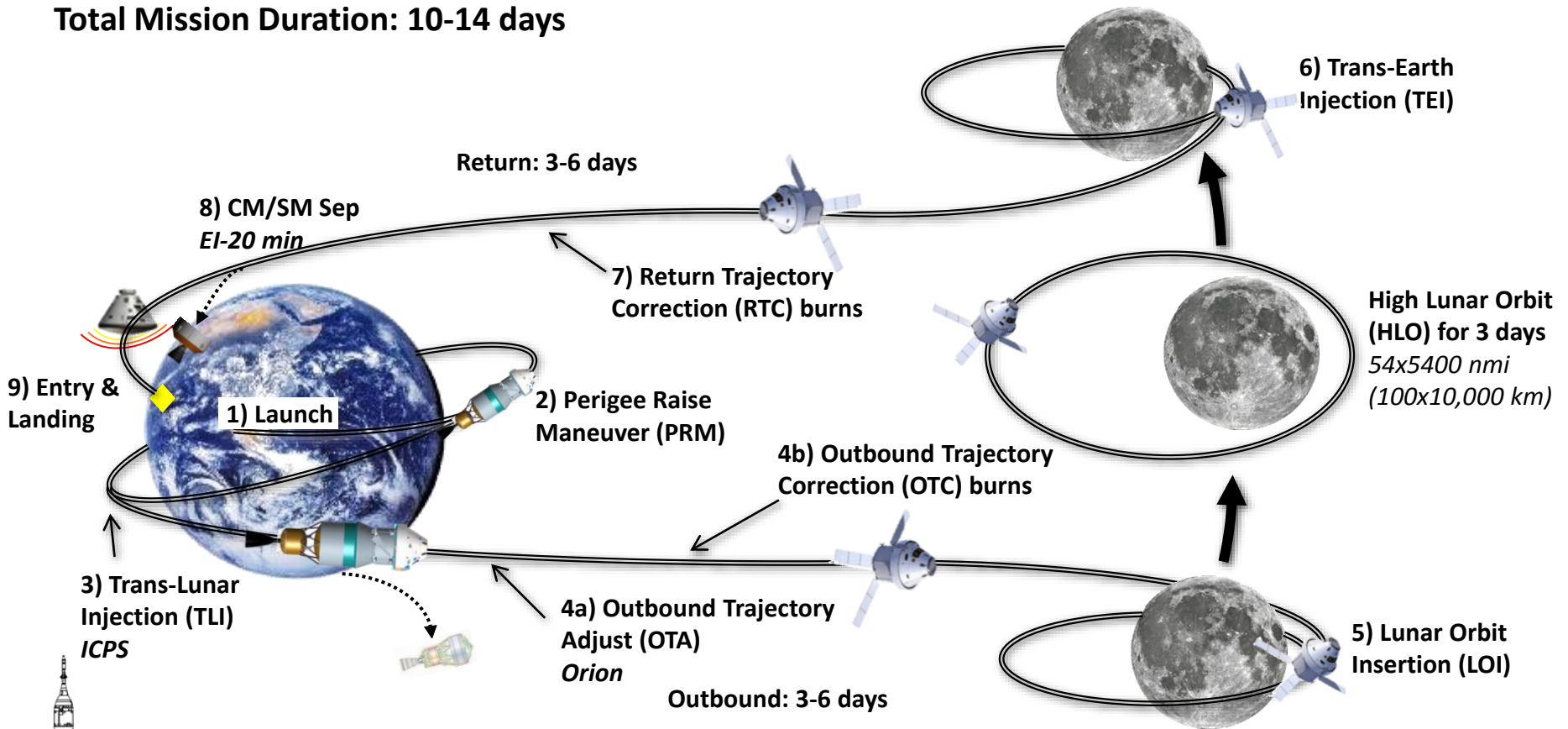
- Demonstrate spacecraft systems performance prior to crewed flight
- Demonstrate high speed entry (~11 km/s) and TPS performance prior to crewed flight
- Landing off the coast of California



# EM-2: Crewed (High) Lunar Orbit



Total Mission Duration: 10-14 days

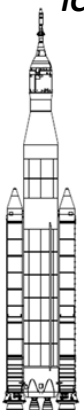


## SLS Configuration:

- 5-seg SRBs and 4 RS-25D
- 28.5 – 35 deg inclination parking orbit

## Objective and Mission Notes:

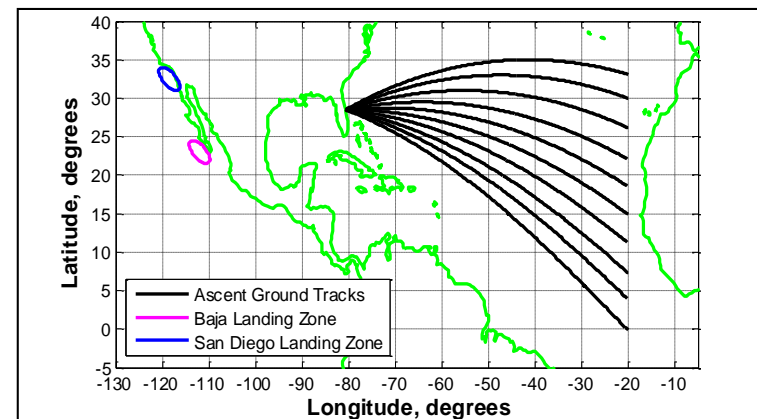
- Demonstrate crewed (up to 4) flight beyond LEO
- Demonstrate baseline Orion vehicle
- TLI places Orion on a lunar flyby free-return trajectory



# Launch Availability

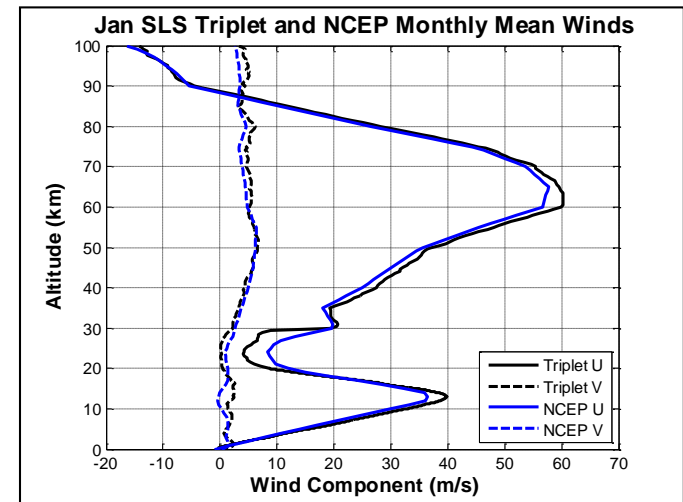
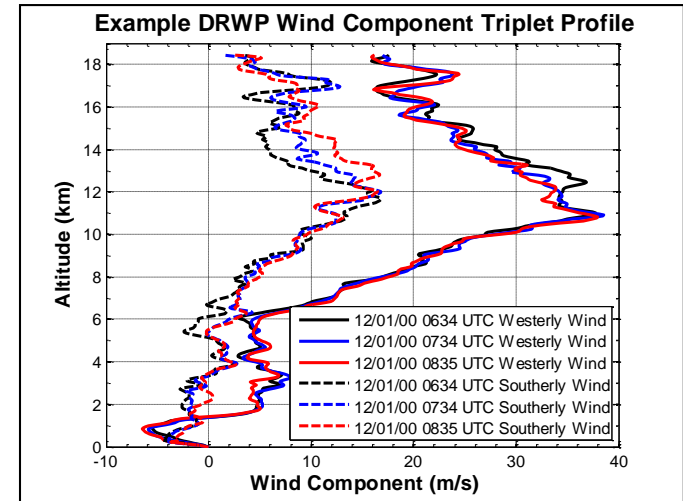
- MSFC NE has an in-house tool to compute the probability of meeting specified constraints for launch.
- Sea conditions are incorporated to overall launch availability assessment for Orion.
  - Segregate global climatology to represent landing areas.
  - Conditions usually worse from Dec-Mar.
- Analysis is tailored to individual launch and landing vehicle constraints.
  - EFT-1 flew on a Delta IV.
  - EM-1 and EM-2 will fly on the SLS.
  - Cargo and uncrewed missions do not require sea condition constraints.
- SLS can fly on different azimuths, which lead to accounting for sea conditions across different ground tracks for EM missions.

Hour (UTC)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
0	77.1	73.6	70.6	81.3	84.8	76.4	85.6	80.4	77.3	75.3	77.5	76.1	78.1
1	77.7	76.6	76.8	81.7	86.3	80.3	87.6	85.5	78.7	79.5	77.9	76.2	80.6
2	76.8	73.3	76.7	86.0	87.9	81.0	91.0	86.2	79.1	78.2	76.9	71.6	80.8
3	74.2	72.1	75.8	85.8	89.1	86.6	94.3	91.1	86.3	77.1	76.6	70.9	82.0
4	77.0	75.2	76.4	86.3	92.0	90.9	94.2	90.1	87.8	80.3	75.1	73.2	83.7
5	70.8	74.8	72.8	87.0	92.4	93.7	96.3	91.9	90.2	79.4	74.3	75.3	83.7
6	70.9	72.6	77.0	85.3	91.2	93.1	95.6	92.6	92.5	81.5	71.8	73.8	83.7
7	72.1	71.6	78.7	82.6	91.3	92.5	94.8	94.4	87.7	81.4	71.0	71.3	83.0
8	68.8	71.1	75.7	84.6	90.9	90.8	95.4	93.7	87.7	79.3	71.0	65.9	81.9
9	65.5	67.0	75.4	79.3	89.1	88.9	92.8	92.1	87.2	78.5	72.4	69.1	80.2
10	64.4	66.2	73.5	77.7	85.2	83.4	91.0	91.6	86.1	78.5	73.5	67.4	78.6
11	59.9	59.1	72.0	74.0	78.6	77.9	82.1	84.3	79.8	72.7	72.8	63.3	73.4
12	59.6	56.1	66.7	74.2	80.6	81.6	86.0	86.7	77.8	67.8	67.0	59.8	72.5
13	59.2	57.8	67.5	75.4	87.8	84.0	88.3	89.6	80.3	73.0	70.7	56.9	74.8
14	69.8	61.3	69.4	76.8	83.8	81.4	90.0	90.6	81.4	74.5	73.1	67.3	76.8
15	72.6	59.9	66.7	76.1	83.4	77.6	88.3	87.5	78.5	73.9	69.3	68.4	75.4
16	71.7	61.3	65.4	74.6	83.5	75.6	83.9	81.7	75.1	73.7	71.7	62.1	73.6
17	68.1	61.1	64.7	74.1	84.1	70.5	77.0	76.2	71.5	71.7	71.0	61.2	71.2
18	68.4	64.4	67.3	74.9	83.6	67.3	74.2	67.0	72.6	72.2	68.6	59.0	70.2
19	68.4	62.9	64.7	75.2	80.4	64.5	72.5	65.4	71.0	69.3	70.2	62.5	69.0
20	68.7	61.9	65.6	77.2	81.1	61.4	70.5	67.5	72.7	74.2	72.3	63.2	69.7
21	71.5	63.1	63.3	77.4	82.7	69.2	69.9	71.8	70.0	70.7	73.8	66.3	70.9
22	71.9	66.6	67.8	76.6	83.1	72.5	72.8	75.5	69.9	74.3	75.1	69.1	73.0
23	74.4	68.4	69.1	77.5	82.8	72.3	77.8	77.7	76.9	75.6	75.3	69.6	74.8
All	70.0	66.5	70.8	79.2	85.7	79.7	85.6	83.7	80.0	75.5	72.9	67.5	76.7



# Wind Profiles for Ascent

- Generated a database of DRWP wind profile triplets.
  - SLS loads and trajectory design (design trajectory, check, fly).
  - Earth-Global Reference Atmospheric Model (Earth-GRAM) characterizes upper atmosphere.
- MPCV program incorporates SLS wind profiles.
  - Goal: Use same winds as SLS.
  - Includes pad and ascent aborts.
  - Ensured that database represents winds for early aborts.
- Determine locations of insufficient water depth for MPCV pad abort landings.



# Summary

- Accounting for environmental dispersions during vehicle design is paramount to success of a space vehicle program.
- Understanding and properly designing for natural environments early in a program mitigate adverse cost, schedule, and risk impacts.
- MSFC NE's TPE has provided terrestrial environments support to MPCV and SLS to ensure robust design, detailed operational planning, and understanding of accepted risks.
  - Define environments across different mission phases.
  - Analyses utilize archives of measured and modeled meteorological data.
  - Iterate with end users to tailor environment for specific applications.
  - Also provided space environment definition.